Understanding the Urban Influences on Santa Monica Bay, CA

INTRODUCTION


Brown pelicans at Malibu Creek Beach.

Santa Monica Bay, offshore of the greater Los Angeles metropolitan area, is a critical resource in terms of fisheries, habitat, and recreation. Many threatened and endangered species, such as the brown pelican and least tern make their homes in the watershed. The bay and beaches also serve as primary recreation resources, supporting a $10 billion tourism and recreation industry. Yet, urbanization and industrialization of the region have stressed the bay's resources and polluted the sediment.


Photo of Santa Monica Bay courtesy of Kevin Snavely, City of Los Angeles, Bureau of Sanitation.

The history of Los Angeles is a relatively short one marked by periods of rapid growth. Over the last 100 years, the population has grown from 100,000 to over 10 million residents in the greater Los Angeles metropolitan area, making it the second largest metropolitan area in the United States behind New York. The demands for waste disposal and the pollution associated with rapid population growth have had a tremendous impact on the bay and its resources. While improvements in sewage treatment, such as updating to secondary treatment, have made a noticeable difference in the health of the bay, it is still in jeopardy. Today, the greatest overall threat to the bay is stormwater run-off.

Sign at the mouth of Malibu Creek warning of polluted stormwater.

Storm drain outfalls empty into various waters sources, which all feed into the bays and oceans. As a result, residual oil and gas on the streets, pesticides, fertilizers, pet waste, and litter all enter Santa Monica Bay. While these individual sources may seem small, the cummulative impact of the increasing population poses a severe threat to water quality. Efforts by the City of Los Angeles Bureau of Sanitation to divert flows from selected storm drains during dry weather to the Hyperion Treatment facility have resulted in full secondary treatment for a portion of the stormwater. Unfortunately, there is still a large amount of untreated stormwater material entering the bay.

Pollutants that enter the bay, whether through sewage disposal or stormwater run-off, bind with the sediment in the bay and are transported or buried with it. Recent studies show that over 90% of the area in the bay has contaminants at levels at which biological effects begin to occur. While pollution in Santa Monica Bay is heavily monitored and researched, most of those studies focus on present conditions. To accurately assess the overall state of the bay and to properly manage its future, it is important to understand historical and present conditions.

Because pollutants bind with sediment, the sediment carries a record of current and historical contaminants. Identifying sediment transport pathways allows for predicting the fate of contaminants, and thus predicting the future health of the bay. To address these issues, the US Geological Survey's Coastal and Marine Group, Southern California Water Research Project (SCCWRP) and the City of Los Angeles, Bureau of Sanitation are studying the sediment of Santa Monica Bay in an effort to document the historical contaminants in the bay, to determine the future of the bay and its resources, and to provide managers with valuable information for environmental decision making.

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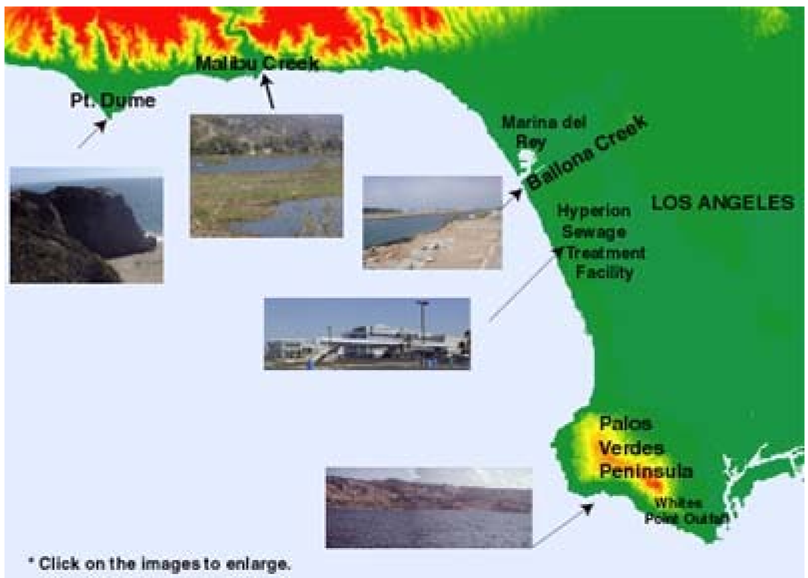
MAP



Location map of primary Santa Monica Bay coastal inputs at:

Point Dume, Malibu Creek, Ballona Creek, Hyperion Facility, and Palos Verdes.

Santa Monica Bay extends from Pt. Dume to the Palos Verdes Peninsula. The primary inputs to the bay are:

- **Malibu Creek**
  Drains a part of the largely undeveloped Santa Monica Mountains;
- **Ballona Creek**
  An urban drainage channel draining the western part of the city and carrying with it all the debris typical of development such as pesticides, fertilizers, oil, gas, and litter;
- **Hyperion Sewage Treatment Facility**
  Discharges through an outfall that is the main discharge point for sewage effluent from the City of Los Angeles;
- **Storm drains**
  Over 69 storm drains empty into Santa Monica Bay. Select storm drains have been linked to the Hyperion Treatment Facility, but others empty untreated runoff directly into the bay.

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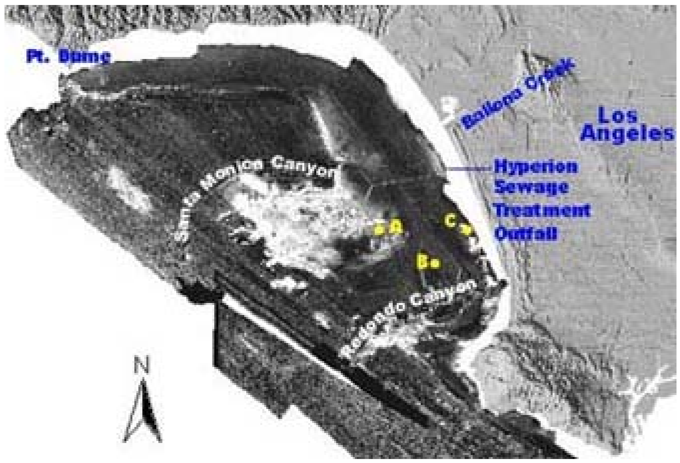
STUDY



Multibeam map of Santa Monica Bay seafloor with images at: hard-bottom, soft-bottom, and ripples sites.

Studying the sediment of Santa Monica Bay required collecting core samples. Before deciding where to collect cores and what type of corer to use, it was necessary to have an idea of the regional geology, especially the relative geology of the seafloor. For example, what type(s) of materials exist on the bottom of the bay? Is it rocky or sandy? To do this, a multibeam bathymetric map of Santa Monica Bay created by the USGS Coastal and Marine Geology Program (shown above) was referenced.

Multibeam data is collected by sending a sound signal toward the seafloor and receiving the returned signal. The time and strength of the returned signal can be used to calculate the depth and the relative geology of the seafloor. In this image, the white areas, (for example, **A** on the map), represent harder materials such as rock, shell, and coarse sand (high acoustic backscatter). Dark areas (for example, **B** and **C** on the map) represent softer, finer materials such as silt and mud (low acoustic backscatter). For more information on prior maps and technique, please see: http://walrus.wr.usgs.gov/pacmaps/.

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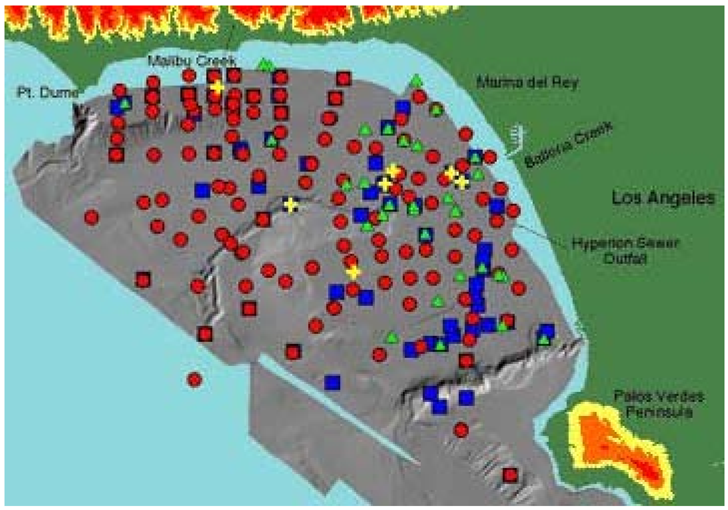
SAMPLING



Sampling map of Santa Monica Bay seafloor.

Core samples , columns of bottom sediment, have been collected by the USGS throughout Santa Monica Bay, and used to answer a variety of questions posed in this study. Above is a shaded relief map showing where cores were collected by USGS scientists throughout Santa Monica Bay. The thirty-five cores that were collected in 1997 (shown as green triangles) are predominantly located on the upper shelf of the bay. One hundred, and twenty-six core samples collected in 1998 (shown as red circles), and eighty-eight core samples collected in 1999 (represented as blue squares), blanket the bay with a fairly even distribution. Seven yellow crosses indicate mooring locations where oceanographic data were collected.

Core samples collected for this study were used to answer two primary questions:

> *How have contaminants changed over time?*
> *What is the future of these contaminants and how will that impact the future of the bay?*

To answer questions regarding historical contamination, cores were analyzed for:

- **geochronology**
  A method of identifying data horizons in cores that corresponded to relative depths in the cores. This establishes the framework by which historical contamination can be studied.
- **contaminants**
  How have concentrations of contaminants such as metals, PCBs, DDT,

PAHs, and sewage waste changed over time?

- **toxicity**
  How has the toxicity of sediments changed historically?
- **microfauna**
  How has historical contamination impacted the bay and its biota?

Methods used to answer questions regarding sediment transport and the fate of contaminants included:

- **Holocene geology**
  Recent history, within the last 10,000 years, of sediment deposition in the bay.
- **clay mineralogy**
  A method for identifying the sources of the sediments in the bay.
- **surface sediment texture**
  Establish baseline information about possible locations where contaminants, as well as bio-habitats, may be concentrated.
- **oceanographic studies**
  Determines sediment transport pathways.
- **bottom photography**
  A format for "ground-truthing" the backscatter data and an additional method for identifying bio-habitats.

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ANALYSIS

GEOCHRONOLOGY

Contaminants bind with sediment particles, therefore it is possible to determine the type of contamination and source of historical pollution by dating cores. Using radio-isotope dating, in this case a lead isotope, relative time periods can be identified at certain depths in the cores. For this study, five key time periods were identified:

- **1900** Before most industrial development in the Los Angeles Basin.
- **1945** Development was accelerating in the Los Angeles Basin.
- **1970** Sediment pollution is thought to have been severe.
- **1985** After steps had been taken to reduce the level of contaminants reaching the bay.
- **1997** Cores were taken, the "present."

Subsamples were taken from the cores at the above corresponding age depths and analzyed for various parameters indicative of pollution, outlined below.

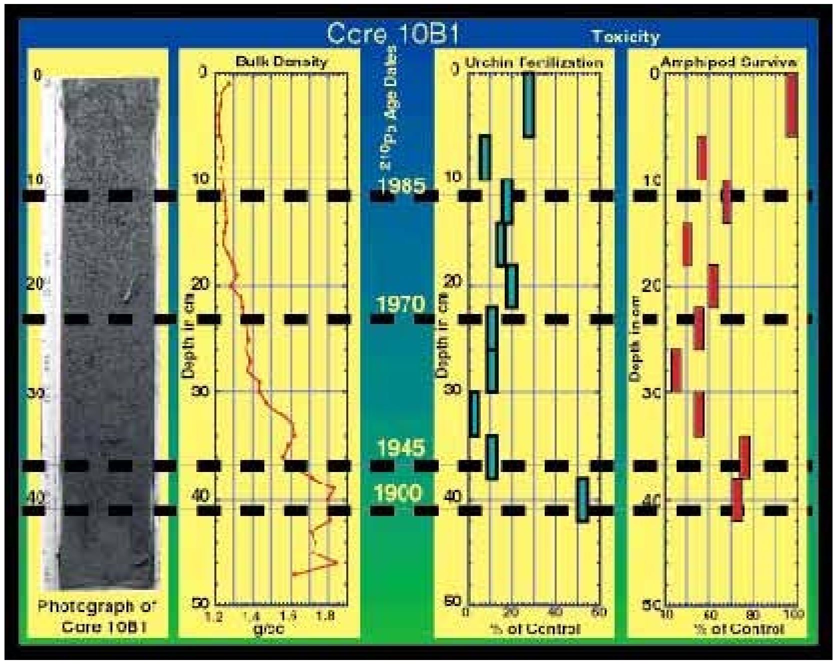
CONTAMINANTS

Subsamples of the cores at corresponding age depths were analyzed for contaminants indicative of sewage pollution, stormwater runoff, and industrial discharge, such as:

- **heavy metals --** from industrial applications, fuel combustion, and tire and brake wear.
- **DDT --** a pesticide used up until the 1970s.
- **PCBs --** used in industrial applications such as transformers until the 1970s.
- **PAHs --** resulting from combustion and/or natural oil seeps.
- **Total Organic Carbon --** an indicator of sewage.

Based on the date horizons, analysis of the cores shows that contaminants have moved vertically throughout the bottom sediment since sludge disposal ended. There is also evidence of contaminants that are far away from the point of sludge discharge. Again, suggesting movement of the sediments and contaminants, as well as mixing of sediment due to burrowing of benthic organisms. In addition, results show that Total Organic Carbon has decreased since sewage sludge disposal from the 7 mile outfall ended.

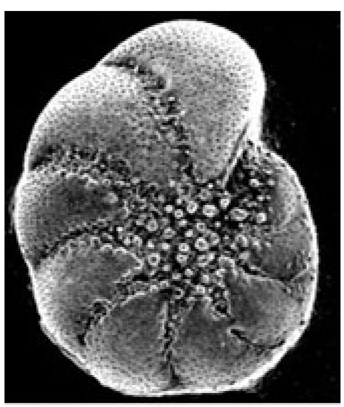
TOXICITY



Above are the results of a toxicity analysis for a core taken near the Hyperion Sewage Outfall pipe in Santa Monica Bay. Two different toxicity tests were used and results were referenced to age dating information and bulk density information derived from gamma-ray logging of the cores. A low bulk density value is commonly associated with effluent affected sediment.

The two tests used were an amphipod (a small shrimp-like creature) survival test, which determines the impact of toxicity within the sediment, and a sea-urchin fertilization test which determines the impact of toxicity in the water column. Results from the tests, in conjunction with radio-isotope dating information, show that toxicity in the sediments is strongest in assocation with the historical discharge of wastewater sludge at the 7 mile outfall pipe. The toxicity of the sediment near the outfall pipe began improving after 1985. This change coincides with improvements in sewage treatment and the closure of the 7 mile outfall pipe.

MICROFAUNA



An example of the foram species Elphidium, which is found in Santa Monica Bay.

Foraminifera (forams) are microscopic single-celled organisms that occur throughout the marine environment. Analysis of forams for parameters such as abundance, whether they are living or dead, and test (shell) deformation, can provide information regarding the environment in which they are found. A local extinction of forams may indicate contamination in a particular area, while an increased abundance may also indicate contamination due to a high nutrient content as a result of sewage disposal.

The object of this study was to assess benthic (bottom dwelling) foraminiferal response to contaminated, and subsequently treated, effluent discharge, specifically from the Hyperion outfall in Santa Monica Bay. Results, based on foram response, show that contamination conditions near the outfall site are improving, but have not yet returned to pre-outfall levels.

HOLOCENE SEDIMENTATION

Understanding Holocene, sedimentation which has taken place in the last 10,000 years, in the bay is an important aspect of determining sediment sources and transport pathways. Concentrations of constituents and the patterns of accumulation provide insight as to the fate of sediments, and thus contaminants.

Long core samples, in conjunction with seismic surveys, were used to determine Holocene sedimentation in Santa Monica Bay. In addition, Carbon-14 dating of shells and organics in the cores helped to identify sediment accumulation in the more recent past.

CLAY MINERALOGY

Clay mineralogy was used to define fine-grain sediment distribution, sources, and transport pathways. Clay minerals, particullarly the mineral smectite, can transport contaminants easily because the contaminants adhere to clay.

The clay mineralogy of samples from throughout the Southern California Bight (from Pt. Conception to the Mexican Border) were analyzed. It was found that most fine-grained sediment is delivered to the continental shelf via rivers, particularly the Santa Ynez and Santa Clara Rivers, during major winter storms. The majority of this sediment is delivered during El Niño years. While rivers have a high water discharge, they do not necessarily carry a lot of sediment. Many rivers in Southern California have been dammed or paved as a method of flood control. This reduces the amount of sediment transported.

The analysis of the clay mineralogy of Santa Monica Bay determined that the fine sediments are a mix of sediments from both north and south of the bay.

SURFACE SEDIMENT TEXTURE

Surface sediment texture, or grain size, provides important baseline data for additional studies. Benthic, or bottom-dwelling, organisms choose their habitat based partially on sediment grain size. Contaminants bind with sediment, therefore, grain size information provides an indication of the concentration of contaminants in a particular location. A correlation also exists between bacterial concentration and grain size. In addition, elative grainsize provides important geologic information, such as the source of the sediment.

OCEANOGRAPHIC STUDIES

USGS scientists prepare to deploy a current mooring that will measure currents as well as additional oceanographic data.

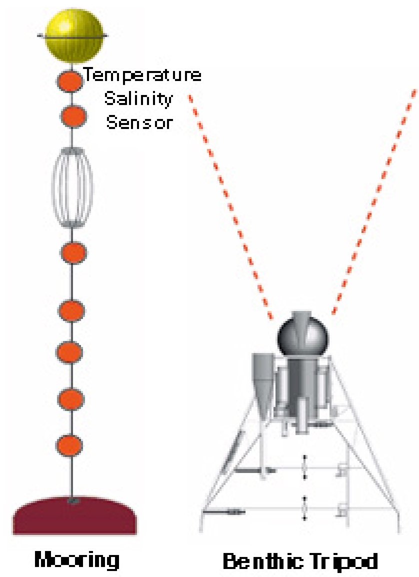


Illustration of a current mooring and a benthic tripod. Both types of instruments are used to collect oceanographic data.

Predicting the fate of contaminated sediment grains requires an understanding of how the sediment is transported. Oceanographic conditions including currents, winds, and waves, play a significant role in transporting sediment. Long-term measurements of such conditions are necessary for constraining predictive sediment transport models.

Current moorings, which measure currents, temperature and salinity throughout the water column, and benthic tripods, which measure similar conditions near the seafloor, have been placed throughout Santa Monica Bay during the 1997-1998 El Niño winter off Marina del Rey, and in other locations (see map) during the 1998-1999 and 1999-2000 winters. Data from these moorings will be used to develop sediment transport models to determine the fate of contaminated sediment in the bay.

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SUMMARY

Results from this study show that the contamination and toxicity of bottom sediments in Santa Monica Bay are decreasing. This decrease coincides with the end of sewage sludge discharge by the Hyperion Sewage Treatment Facility in 1987, and improvements in overall sewage treatment. Dating of the cores shows that there is vertical movement of contaminants. Pollutants, such as DDT,are found at time periods before the chemicals had been manufactured, indicating subbottom movement of the sediment. Most likely, this was due to bioturbation caused by burrowing of benthic organisms.

Water quality studies show that discharge from Ballona Creek has an impact on water quality while discharge from Malibu Creek has a negligible impact. Ballona Creek drains a largely developed area of Los Angeles, while Malibu Creek drains a largely undeveloped portion. The results of this study indicate that stormwater run-off has a great impact on water quality in Santa Monica Bay.

Data from this study will also be used to develop sediment transport models, designed to demonstrate the possible fate of sediments, and thus contaminants in Santa Monica Bay. This information will be valuable for future decision making regarding the bay and its resources.

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REFERENCES

USGS websites related to this project:

- The California Urban Ocean Project
  http://walrus.wr.usgs.gov/research/projects/urbanocean.html
- USGS Western Coastal and Marine Geology Team
  http://walrus.wr.usgs.gov/
- CABRILLO: Southern CAlifornia Bight Regional Investigations - Life, Land, and Ocean
  http://walrus.wr.usgs.gov/cabrillo/
- Data related to this and other Coastal and Marine Geology projects
  http://walrus.wr.usgs.gov/infobank/
- 1998 Study: Distribution and Fate of Contaminated Sea-floor Sediment on the Shelf Offshore Los Angeles
  http://walrus.wr.usgs.gov/pv/

Cooperating organizations on this project:

- Southern California Coastal Water Research Project (SCCWRP)
  http://www.sccwrp.org/
- The City of Los Angeles, Bureau of Sanitation
  http://www.lacitysan.org/
- Skidaway Institute of Oceanography
  http://www.skio.usg.edu/
- Woods Hole Oceanographic Institution
  http://www.whoi.edu/

Other site related to Santa Monica Bay:

- Heal the Bay
  http://www.healthebay.org/

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Gorsline, D.S, 1992. The geological setting of Santa Monica and San Pedro Basins, California Continental Borderland. *Prog. Oceanog.* 30:1-36.
National Marine Fisheries Service, 1997
Schiff, K. and Weisberg, S., 1999. Iron as a reference element for determining trace element enrichment in Southern California coastal shelf sediments. *Marine Environmental Research* 48:161-176.

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POINT DUME

Point Dume, California.

Santa Monica Bay lies offshore of Los Angeles and is bound the Los Angeles Coastal Plain and the Santa Monica Mountains onshore, by Pt. Dume to the north, and the Palos Verdes Peninsula to the south. The mountainous landform is largely the result of the slow collision of the Pacific and North American tectonic plates; the San Andreas fault marks the point of friction between the two. Sediment eroding from four surrounding mountain ranges over the last 2 million years has filled the habitable portion of the Los Angeles Coastal Plain to its present elevation near sea level.

PALOS VERDES

Portugese Bend Landslide, Palos Verdes, California.

Sediment is brought to the coastal zone via rivers. Damming of the rivers and channelization have reduced sediment input. Additional sediment is added by the erosion of the coastal bluffs and cliffs, and landslides, such as that in Palos Verdes, known as the Portugese Bend landslide.

BORDERLAND

Map of the California Continental Borderland from Gorseline, 1992.

Offshore, Santa Monica Bay is bound by the Santa Monica Basin, which is one of 23 basins that comprises the California Borderland Complex. The Borderland Complex was initiated 30 million years ago when the North American Plate overrode the East Pacific Mid-Ocean Ridge.

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MALIBU CREEK

Malibu Lagoon, California.

Malibu Lagoon, which is at the mouth of Malibu Creek, empties into Santa Monica Bay. Malibu Creek drains a part of the largely undeveloped Santa Monica Mountains. The lagoon and creek provide habitat for a number of birds and fish, including a Steelhead Trout run located in Malibu Creek. For more information about Malibu Creek and its watershed visit: Heal the Bay.

BALLONA CREEK

Lower Ballona Creek near Playa del Rey Beach, California.

Ballona Creek is an urban drainage channel which drains the western part of Los Angeles carrying with it all the debris typical of development such as pesticides, fertilizers, oil, gas, and litter. Above is a photo of Ballona Creek closer to its outlet on Playa del Rey Beach. Marina del Rey is in the background.


Ballona Creek, California.

The above photograph was taken further up Ballona Creek. As a means of flood control, some creeks and rivers in Southern California have been paved. Creeks, rivers, and streams transport sediment to the coast. Paving of the banks has led to a decrease in sediment transport, which limits the supply of coastal sand, possibly impacting coastal erosion. The paving of creeks and streams may increase contamination by reducing the amount of "clean" sediment available to bury contaminants. In addition, this increases the amount of contaminated sediment because the sediments transported to the coast via paved rivers and creeks are largely from run-off. For more information on Ballona Creek and its impact on Santa Monica Bay, visit: Heal the Bay.

As part of this study, water quality throughout Santa Monica Bay was tested. Results show that discharge from Ballona Creek is contaminated and impacts water quality, while pollution from discharge from Malibu Creek is neglible. Since Ballona Creek drains a developed portion of Los Angeles, and Malibu Creek drains a largely undevloped portion, results from water quality sampling would indicate that stormwater run-off, containing anthropogenic (influenced by humans) pollutants, has an impact on water quality in Santa Monica Bay.

HYPERION


Hyperion Sewage Treatment Facility, Playa del Rey, California.

The Hyperion Treatment Plant, located in Playa del Rey, has been operating since 1894. Today it has the capability of treating 420 million gallons per day. Treated sewage is discharged through a 5-mile outfall pipe into the bay. A one-mile discharge pipe, previously used for discharge, is now used only for emergencies. A 7-mile sludge (the solids that settle out after primary treatment) outfall was operational until 1987, when Hyperion made a committment to upgrade to secondary treatment. In 1988, Hyperion began discharging 100% secondary treated wastewater. Such improvements to the facility and in sewage treatment have greatly reduced point source contamination in the bay. For more information on the Hyperion Treatment Plant and its history, visit: The City of Los Angeles, Bureau of Sanitation-Hyperion Treatment Plant.

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PHOTOS

Comparison of these photos with the backscatter image provides information about not only the surficial geology, but where key habitat areas may be located. High acoustic backscatter, or rocky, areas are more likely to have a greater abundance of plants and animals than low acoustic backscatter, or sandy, areas.

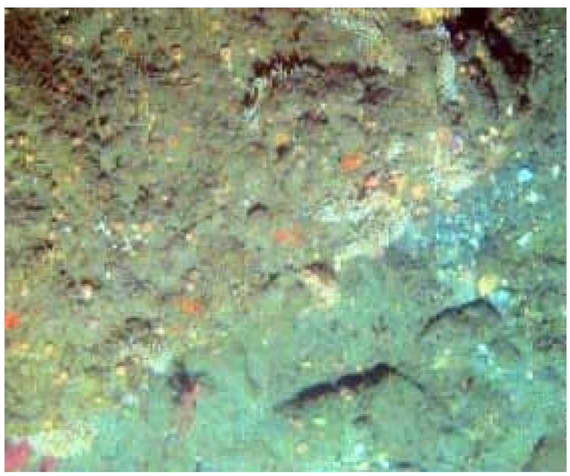

Photo of a hard bottom, an example of a high acoustic backscatter area.

This is an example of a high acoustic backscatter, or rocky, area which appears white on the backscatter image. The rocks are covered in a thin blanket of sediment, corals, and plants. Rocks provide a substrate, or base, on which plants and corals can grow, and thus are an important base for bio-habitats. Compare the growth in this photograph to the photograph below of a sandy region. There are "critters" that frequent these sandy areas, but the biota (plants and animals) are not as abundant.

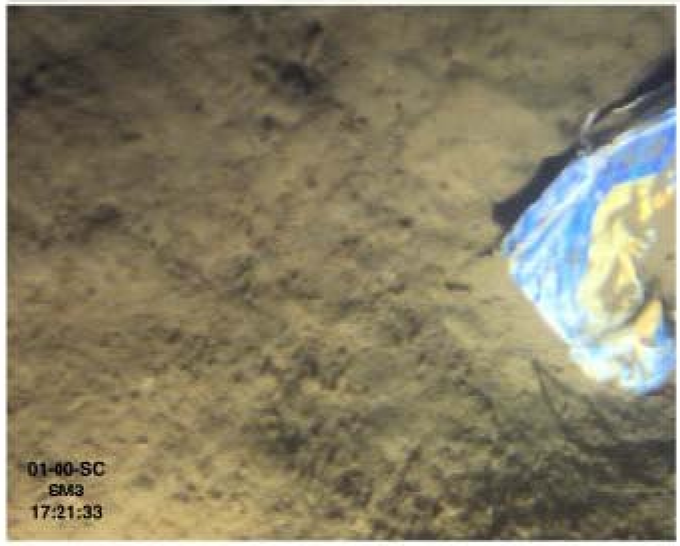

Photo of a soft bottom, an example of a low acoustic backscatter area.

The soft bottom habitats are also important areas for habitat. If you look closely, you can see that there are small holes in the surface of the sand in the photograph above. These holes are an indication of burrowing animals. Burrowing animals mix the sediment in a process called bioturbation. This is important to understand because this mixing of sediments can re-introduce previously buried contaminants to the water column. In addition, burrowing organisms are living in and feeding on these sediments and contaminants. Those animals are then eaten by bottom dwelling organisms, which are then eaten by larger fish and other animals. Any contaminants that the burrowing organisms have ingested are passed up the food chain. These contaminants intensify in each animal higher up the food chain, in a process that is known as bioaccumulation. These contaminants can be passed on to humans when they eat fish from contaminated habitats.

This photograph also shows evidence of the human impact on Santa Monica Bay, note the trash on the right side of the photograph. Trash thrown overboard from boats, or left on beaches to blow into the water, or discharged to the bay through storm drains is visible evidence of pollution. Additionally, pesticides, fertilizers, oil, gas, and pet waste, which cannot be seen, enter the bay through stormwater run-off.

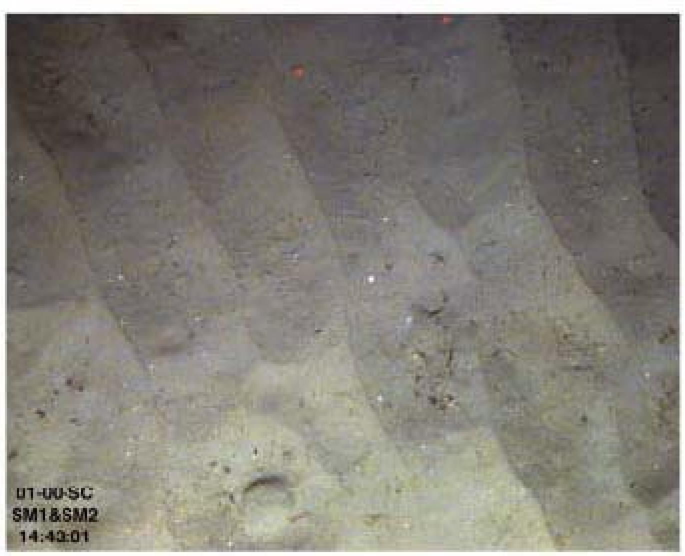

Photo of sand ripples in a soft bottom, from an area of low acoustic backscatter.

This photograph is of a sandy area closer to shore. Sand ripples, which give an indication of the direction of water flow in this area, are present.

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CORING

Studying the sediment of Santa Monica Bay required collecting core samples - essentially tubes that contain a column of the seafloor. Core samples provide information about the history of the bay and how the seafloor formed. Analyzing portions, or subsamples, of the cores, provides information about the various materials in the ocean and their origin, including pollutants.

Box corer.

There are various methods used to collect core samples. This is a picture of a box corer. This type of corer can penetrate the seafloor up to 60 cm in depth. The result is a "box" of sediment that can then be divided, using tubes, into multiple cores. This method allows for the collection of multiple cores all from the same location to be analyzed independently for various aspects of this study.

Piston corer - Photograph courtesy of Chris Sommerfield.

A piston corer, a type of long corer, can penetrate to a depth of a few meters depending on the subsurface bottom type. The corer is driven into the seafloor using a piston.

A split vibracore from Santa Monica Bay.

This photograph shows across-section of the length of a vibracore. A vibracore is another type of long corer which uses a vibrating force to drive the core into the sea floor. Long cores allow geologists to look further back in time. The deeper the core, the more information geologists can collect regarding the history of the seafloor and sediment deposition.

In the photograph, the line separates two different types of seafloor, created in two different environments. Above the line the material is rocky, below the line the sediment is finer and primarily mud. This core indicates that, at one point in time, this area of the seafloor was actually an estuary. That is when the muds were deposited. Then, the shoreline transgressed, or moved inland, depositing sand and mud, that was originally offshore of the estuary, over the estuarine sands. This process is commonly the result of sea-level rise.

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